US-PAT-NO: 6597371

DOCUMENT-IDENTIFIER: US 6597371 B2

TITLE: System for digitally driving addressable pixel matrix

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Brief Summary Text - BSTX (5):
Applicant's prior U.S. Pat. Nos. 5,248,971; 5,515,046; and 5,569,315 describe a focal plane imager (or camera) which utilizes a multiplexed oversampling analog to digital modulation technique to produce an output bit stream for displaying the focal plane image on a monitor. The disclosures in these patents are, by **reference,** incorporated herein.

Brief Summary Text - BSTX (12):
In a preferred embodiment of the present invention, an oversampling data modulator provides a one-bit data stream for each display pixel. Each data stream, which essentially has the form of a **pulse density** modulated signal, directly drives a single display pixel to pulse it either on or off to produce a real time apparent gray or color scale pixel image to the eye of an observer. The psycho-physical response of the human eye acts as a low pass filter allowing it to extract a flicker free image from the entire matrix of display pixels.

Detailed Description Text - DETX (10):
The use of an oversample bit stream to modulate a pixel offers improvement in display quality as compared to existing analog and alternate digital

approaches. The key areas of improvement are linearity, bandwidth and dynamic range. Analog displays such as cathode ray tubes (CRT) and field emission displays (FED), typically exhibit a non-linear intensity response to an applied analog signal voltage that varies for different displays. To correct for this, the display manufacturer typically measures the response and develops a **gamma correction** curve which is applied to improve linearity. In contrast, a system in accordance with the invention can turn the display pixels fully on or off, (where M=1) depending on the on/off timepulse density to produce an average intensity variation. This avoids the typically nonlinear characteristic of an analog value.

Detailed Description Text - DETX (11):

It has been experientially determined that to produce a flickerless response with eight bits dynamic range, a system in accordance with the invention should pulse each pixel at a frequency in the range of 250-700 Hz, e.g., 420 pulses per second per pixel. To achieve this pulse rate, an analog CRT would have to increase its raster scan rate to 420 frames per second, fps. However, though frame rate increases, the bandwidth of the data on the electron guns is actually lowered. At a nominal 60 fps for flicker free display, an analog display must have 336 Hz information bandwidth per pixel, equivalent to about 480 bits per second. This is also true for digital displays that use pulse width modulated input video data. For digital displays that are pulse width modulated, the bandwidth problem is even more severe. These displays must divide the frame interval into 256 time intervals (FIG. 2B) to provide eight bits of gray scale. At 60 fps, this requires 15,360 **switches** per second, i.e.,

a 65 microsecond time interval. This is considerably higher than is required by systems in accordance with this invention. Dynamic range limitation is the most severe problem for modern displays because of these timing requirements. Newer video displays such as ferro-electric liquid crystal (FLD) and digital micromirror device (DMD) do not generally achieve the dynamic range they are theoretically capable of due to the pulse width modulation schemes used to drive them. For example, an FLD seldom achieves better than 500 microsecond frame update times. Dividing this time into a 60 fps display rate allows 33 time increments per frame for gray values or of five bit dynamic range. Systems in accordance with the invention operating at this **switch** rate, i.e., 2,000 pulses per second, will provide greater dynamic range at the video display, e.g., up to 10 bits.

Detailed Description Text - DETX (12):

Line A of FIG. 2 represents an analog amplitude modulated signal subject to nonlinearity error. Line B of FIG. 2 represents a pulse duration modulated approach. Even though only one edge transition is shown for each frame, its position is independent for all pixels thus requiring frame updates at all allowable positions. Line C depicts a one-bit **pulse density** data stream in accordance with the present invention. Whereas large amplitude harmonics at 60 Hz exist in the frame approaches, i.e. FIG. 2, lines A, B, a system in accordance with line C reduces these harmonics or pushes them up in frequency above the eye response. The number of **switching** transitions is also typically much greater in line C thus reducing incoherent noise due to clock jitter. Line C depicts edge times t.sub.0, t.sub.1 and t.sub.x. The interval t.sub.0

-t.sub.1 represents the shortest bit stream interval for turning a pixel on and then off. Lines A and B depict a sequence of n frames which are assumed to occur at F1=60 frames per second. To produce 420 pulses per second (F2) in accordance with the bit stream of line C, edge time t.sub.x occurs substantially at (F2/F1)n.

Detailed Description Text - DETX (26):
The characteristics of the human eye can cause artifacts which appear as noise when an on/off **pulse density** data stream is used to create apparent gray levels. The eye has a known time response curve that generally follows the equation,

Detailed Description Text - DETX (27):
where t is time in seconds and f(t) is the response to a unit increase in light intensity. This equation shows the behavior to be equivalent to a low pass filter with a very broad roll off. For a **pulse density** modulated data stream, if the modulation rate is sufficiently high, the modulation carrier frequency will be filtered out passing only the modulating information. However, at very low **pulse densities,** an individual pulse is perceived as a pulse of light rather than an average value of **pulse density** as the above equation would predict. Depending on light intensity, this break down generally becomes noticeable at about 20 pulses per second. If a modulation bias is added into the **pulse density** stream as shown at 130 in FIG. 5 such that the lowest pulse rate will be above 20 pulses per second, then individual pulses will not be observable. Since the eye perceives black and white as relative values this can be done without changing the perception of various

shades of gray from black to white. Black will be seen at the 20 light pulses per second intensity rather than zero light intensity.

Claims Text - CLTX (5):

5. The apparatus of claim 4 wherein each of said addressable pixels defines either a first on state or a second off state; and wherein each of said output streams functions to **switch** one of said addressable pixels between said on and off states.

Claims Text - CLTX (6):

6. The apparatus of claim 3 wherein each of said output streams is defined by a variable **pulse density** signal.